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EARLY USE OF THE ROENTGEN RAY IN THE STUDY OF THE ALIMEN- TARY CANAL*

W. B. CANNON, M.D.

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My reasons for preparing the present paper were various. First of all, I must confess to never having carefully looked up the historical sequence of early literature on the technic of applying the Roentgen rays to the alimentary canal, and I wished to do that. Second, an account of the first Roentgen-ray experiments on the digestive tract performed in the Harvard Physiological Laboratory has never been written, and that, I thought, might be interesting to members of the American Roentgen Ray Society. Finally, my activities during the past few years have not been concerned with use of the Roentgen rays, and when asked to speak here, I had nothing else to bring than the story of these early observations.

When in December, 1895, Roentgen¹ announced the discovery of a "new kind of rays," he pointed out that the salts of metals, either solid or in solution, behaved generally as the metals themselves, in obstructing the passage of his new rays.¹ Within two months, in February, 1896, the possibility of rendering hollow organs visible by injecting them with salts was demonstrated by Dutto,² who filled arteries with plaster of Paris and then photographed them. A month later, in March, 1896, Becher³ published a roentgenogram of a dead guinea-pig in which he had distended the stomach and a loop of the small intestine with lead subacetate; the stomach shadow was quite indistinct, but the intestinal loop showed clearly. In April, 1896, Wegele⁴ suggested

* Read at the fourteenth annual meeting of the American Roentgen Ray Society, Boston, Oct. 2, 1913.

1. Roentgen: Translation of the original paper in *Science*, 1896 N. S. iii, 227.

2. Dutto: *Rendiconti, Reale Accademia dei Lincei*, 1896, v, 129.

3. Becher: *Deutsch. med. Wchnschr.*, 1896, xxii, 202.

4. Wegele: *Deutsch. med. Wchnschr.*, 1896, xxii, 287.

that it would be possible to introduce a spiral electrode into the human stomach and by roentgenographing it to determine the limits of the greater curvature; it was not until a year later, however, that the suggestion was carried out by Lindemann,⁵ who introduced a soft stomach-tube enclosing a fine copper wire and obtained a roentgenogram of the wire as it lay along the lower gastric border. Meanwhile Hemmeter,⁶ having noted Becher's roentgenogram of the dead guinea-pig with stomach and intestine made visible by injected lead salts, and having recently devised an intragastric bag, proposed that the bag be pushed into the stomach and filled with a solution of lead acetate to render the shape of the stomach capable of being roentgenographed. I am not aware that Hemmeter's proposal was ever put to practical test.

In the fall of 1896, when I was a first-year student in the Harvard Medical School, and Mr. Albert Moser, a Cambridge acquaintance, was a second-year student, we went to Prof. H. P. Bowditch and asked for an opportunity to undertake a physiologic investigation. He suggested that we test by means of the newly discovered Roentgen rays the Kronecker-Meltzer view of deglutition—namely, that substances when swallowed are shot down the esophagus by pressure developed in the mouth, and are not pushed down by a peristaltic wave. A small static machine and some simple tubes were secured, and we set to work. Our first observation was made on Dec. 9, 1896, when we watched globular pearl buttons pass down the esophagus of a dog. On December 14, we repeated the observations on a rooster whose neck was kept straight by fastening the head and body in fixed positions.

That substances vary in their opacity to the Roentgen ray in accordance with their molecular weight was then common knowledge. Barium and bismuth were selected from among the heavy metals, and barium sulphate and bismuth subnitrate were chosen as salts which, because practically insoluble, would serve our purposes. Since bismuth subnitrate was a pharmacopeial preparation we determined first to use that.⁷ On Dec. 16, 1896,

5. Lindemann: *Deutsch. med. Wchnschr.*, 1897, xxiii, 266.

6. Hemmeter: *Boston Med. and Surg. Jour.*, 1896, cxxxiv, 609.

7. Later I showed that barium sulphate mixed with the food was quite as satisfactory as bismuth subnitrate. Cannon, W. B.: *Am. Jour. Physiol.*, 1904, xii, 388.

we gave a frog a gelatin capsule filled with this bismuth salt, and after seeing clearly the shadow of the substance in the frog's stomach, we repeated, the next day, December 17, the use of the salt in a capsule to show deglutition in the dog. When the swallowed capsules were dissolved, the bismuth subnitrate was liberated; and in my notes I find the remark that thus a dark roundish area was produced as a stomach shadow. Then we procured a goose and made for it a box so arranged that the long neck reached up through the cover. A high cardboard collar was then attached to the top of the box in such a way that it could be closed in front when surrounding the goose's neck. Thus the goose, with the appearance of using the most stylish neckwear, presented to the fluorescent screen a very satisfactory extent of esophagus. At the meeting of the American Physiological Society in Boston, Dec. 29, 1896, the phenomena of deglutition as exhibited by the goose when swallowing capsules containing bismuth subnitrate was informally demonstrated to the members by means of the Roentgen rays. This was, I think, the first public demonstration of movements of the alimentary tract by use of the new method.

It was not until Jan. 9, 1897, that we employed bismuth subnitrate mixed with the food (in this case a bread mush) to render the swallowed mass visible. And in order to test the rate at which substances with different consistencies move along the esophagus, we added more or less water to the mush, thus varying its physical state from a rather stiff mass to a very soft, nearly fluid mixture. Various observations of this nature were made on the goose in January, February and March, 1897. On April 3, 1897, we began using the same mush-bismuth bolus, and also meat with bismuth subnitrate adherent, in a study of swallowing in the cat, and as the mixture of bismuth subnitrate and food accumulated in the stomach, that organ was outlined by a dark shadow. On April 3, and in observations on several days thereafter, the gastric contents became visible as the cats swallowed more and more of the mixture, but no movements of the wall were seen. Finally, on April 23, 1897, a cat was fed bread soaked in warm water, and mixed with bismuth subnitrate; about an hour and a half later peristaltic waves were clearly seen passing over the organ. Following is a transcript of my notes taken at the time:

"A constriction seemed to start at *A* (*A* referred to a drawing and indicated the middle of the stomach), making a clear line there and forcing a black round mass into the region of *B* (the pyloric region). The constriction passed downward from *A* to *C* (the pylorus), but as the pylorus did not give way the contents of the stomach at *B* (the pyloric region) were forced back through the constricted ring. . . . As soon as the constriction had passed from *A* to *C*, it began again at *A* and the food was thus squirted through the narrow orifice caused by the constriction. This process continued a number of times, the food in region *D* (the cardiac region) apparently not at all involved in the movement." Forty minutes later the gastric movements were seen going on in the same manner.

The foregoing description records the first observation of peristaltic waves passing over the stomach contents, as seen by the Roentgen rays when the ingested food was mixed with a bismuth salt. Later observations refined the description—thus it was soon found that several waves are present at the same time—but the main facts, that the waves start at about the middle of the stomach, and that, because the pylorus does not open at the approach of every wave, these moving constrictions churn the food in the pyloric end—these facts were noted with this new method at first glance.

At a meeting of the American Physiological Society in Washington, May 4, 5 and 6, 1897, a preliminary report of these observations was presented by Professor Bowditch, and the summary of the report was published a month later.⁸ A part of the summary was as follows:

"For this purpose (studying the esophageal and gastric movements by means of Roentgen-ray shadows) moist bread, meat, mush or viscid fluids were mixed with bismuth subnitrate. Food thus prepared is visible during the process of deglutition, and, if given in sufficient quantities, serves to outline the stomach and to render its peristaltic movements visible." Then followed an account of the results which had been obtained in observing deglutition in different animals, and also gastric peristalsis.

This was not the first published account of the use of bismuth subnitrate to make visible the alimentary tract. About two months before (April 20, 1897) Rumpel⁹ published the report of rendering a pathologically dilated esophagus visible by pouring into it 300 c.c. of a 5 per cent. suspension of bismuth subnitrate. The

8. Science, June 11, 1897, p. 901.

9. Rumpel: München. med. Wehnschr., 1897, xliv, 420.

account of work done in the Harvard laboratory which was published June 11, 1897, was, however, so far as I have been able to learn, the first record of the use of a heavy salt mixed with the food—the method now employed—to render visible by means of the Roentgen rays the movements of the alimentary tract and the effects of these movements on the contents.

At the meeting of the Société de Biologie in Paris, June 12, 1897, about five weeks after the meeting of the American Physiological Society in Washington, Roux and Balthazard¹⁰ reported observations on gastric peristalsis in the frog, studied by means of the Roentgen rays. They also used food mixed with bismuth subnitrate. These observations were followed by others on the stomach movements of the dog and of man (July 24, 1897).¹⁰ Roux and Balthazard¹¹ gave to their human subject 15 or 20 gm. of bismuth subnitrate suspended in 100 c.c. of water. They were the first investigators to use the method to examine peristalsis of the human stomach, but they succeeded in seeing only the lower part of the greater curvature.

The work on cats was continued in Harvard laboratory during the summer and fall of 1897. The results of this labor were reported at the meeting of the American Physiological Society, Dec. 28, 1897, and published in the *Proceedings*, April 1, 1898.¹² The completed work on the movements of the stomach appeared in May, 1898.¹³ Later accounts of the movements of the small and large intestines and of the rate of passage of different foodstuffs through the alimentary canal, all studied by the same method, were published from the Harvard laboratory,¹⁴ and these papers, together with the paper on deglutition, finished the non-experimental, purely observational studies.

In the work on deglutition Mr. Moser and I, in the fall of 1897, made observations on a girl aged 7 and saw clearly capsules containing bismuth subnitrate, boluses of bread and milk mush mixed with the salt, and also a suspension of the salt in water, passing down the esophagus.¹⁵

10. Roux and Balthazard: *Compt. rend. Soc. de biol.*, June 18, 1897.

11. Roux and Balthazard: *Compt. rend. Soc. de biol.*, 1897, xvii, 567, 704, 785; *Arch. de physiol.*, 1898, xxx, 85.

12. *Am. Jour. Physiol.*, 1898 i, p. xiii.

13. *Am. Jour. Physiol.*, 1898, i, 359.

14. *Am. Jour. Physiol.*, 1902, vi, 251; 1904, xii, 387.

15. *Am. Jour. Physiol.*, 1898, i, pp. xii and 435.

In 1898 and in 1899 Dr. Francis H. Williams and I made some studies on the changes in shape of the human stomach as it empties. A boy aged 10 and his sister aged 7 were the subjects of our examinations. The boy was fed a pint of bread and milk to which 30 gm. of bismuth subnitrate had been added; his sister received a smaller amount. Tracings were made on transparent paper laid over the fluorescent surface. These tracings show clearly the vertical position of the stomach now so well known, and a gradual shortening of the organ as it discharges its contents. These records were not published at once, but appeared in 1903.¹⁶

A year after this publication by Dr. Williams, Rieder¹⁷ reported his thorough study of the alimentary canal in man. The method used by Rieder was that which had been used many times before. Rieder himself definitely stated in his more extended paper in 1905 that his use of bismuth subnitrate mixed with the food, as a means of rendering opaque to the Roentgen rays the contents of the alimentary canal, was not new, and he presented a review of previous work in which this method had been employed.

In spite of Rieder's disavowal of the introduction of any new principle into methods of gastro-intestinal examination, it is not uncommon nowadays to find in clinical literature, especially in Germany, the use of a heavy salt mixed with the food to make Roentgen-ray shadows, referred to as "Rieder's method."¹⁸ The assertion made by those who credit Rieder with the method is that he was first to demonstrate that giving large amounts of bismuth is harmless for the human organism (Albers-Schönberg¹⁸ and Krause and Schilling¹⁸). It is doubtful if bismuth subnitrate is as assuredly harmless as was assumed in the early days.¹⁹ Be that as it may, Groedel¹⁸ has pointed out that Rieder's use of massive doses of bismuth subnitrate (from 40 to 50 gm.) rested in fact on the long experience of internists who, following Kussmaul, had given for gastric ulcer large doses—doses which would result in as much as 60 gm. being in the digestive tract at one time. This

16. Williams, Francis H.: *Roentgen Rays in Medicine and Surgery*, New York, the Macmillan Company, 1903, p. 365.

17. Rieder: *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1905, viii, 141.

18. Groedel: *München. med. Wchnschr.*, 1907, liv, 1068. Albers-Schönberg: *Med. Klin.*, 1908, iv, 1713. Krause and Schilling: *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1913, xx, 465.

19. Worden, Sailer, Pancoast and Davis: *Univ. Penn. Med. Bull.*, 1906, xix, 131, 137.

tendency to ascribe to Rieder the shadow method of studying the alimentary canal is not, however, confined to Germany. A recent article²⁰ in this country on Roentgen technic begins thus:

The fundamental principle of Roentgen-ray examinations of the stomach and intestine is the visualization of their outline by filling them with substances opaque to the ray, a principle which we owe to Rieder of Munich who, in 1904, first used bismuth subnitrate for the purpose.

As already stated, Rieder himself clearly disclaims any such credit as is thus given to him.

The evolution of the Roentgen-ray shadow method of examining the digestive tract has gone forward with such great strides in these later years—with the manufacture of powerful electric generators and durable tubes and with the application of the method to all manner of practical problems of diagnosis, such as constipation, and obstruction, and tumors, and ptosis and what not else—that the small beginnings which I have recounted here seem trivial enough. This historical review which I have tried to present may, however, serve to show that the use of Roentgen-ray shadows of gastro-intestinal contents, to determine normal and pathologic motions of the alimentary tract, has been a gradual development. The interdependence of ideas in any such development is so complex that it is quite possible that the method now employed originated in fact in the statement contained in Roentgen's first announcement, that the salts of heavy metals are as opaque to the rays as the metals themselves. The injection of blood-vessels and intestinal loops with salts showed almost at once that any hollow organ could be made, in the presence of Roentgen rays, to manifest its contours. The mixing of heavy salts with the food to render gastro-intestinal movements visible was, so far as I have been able to learn, first used in the Laboratory of Physiology in the Harvard Medical School; but the method contained, to my mind, no principle which had not been utilized before. Under these circumstances there is little warrant for any man to claim for himself or for any other the credit of inventing the method now used everywhere in Roentgen examinations of the alimentary canal.

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20. Carman, R. D.: The Technic of Roentgen-Ray Examination of the Gastro-Intestinal Tract, and the Interpretation of Screen and Plate Findings, *THE JOURNAL A. M. A.*, Aug. 2, 1913, p. 321.

